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DaimlerChrysler AG

Method for regenerating a nitrogen oxide storage catalytic converter

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The invention relates to a method for regenerating a nitrogen oxide storage catalytic converter arranged in an exhaust pipe of an internal combustion engine with the features of the precharacterizing clause of
10 claim 1.

Laid-open specification DE 101 13 947 A1 describes a method for regenerating a nitrogen oxide storage catalytic converter arranged in an exhaust pipe of an
15 internal combustion engine. Nitrogen oxide storage catalytic converters are used in particular in motor vehicles which have an internal combustion engine which can be operated with an air/fuel mixture alternating between clean and rich conditions. During operation
20 with a lean air/fuel mixture, the barium carbonate which is present, for example, in the catalyst material of the nitrogen oxide storage catalytic converter removes nitrogen oxide (NOx) from the exhaust gas, which is at that time oxidizing, to form solid barium
25 nitrate. On account of the associated load imposed on the material, from time to time it is necessary to regenerate the NOx storage catalytic converter. This process, which is known as nitrate regeneration, is effected by operating the internal combustion engine
30 with a rich air/fuel mixture for a certain time. The barium nitrate, which is unstable in the resulting exhaust gas containing reducing agent, in the process decomposes again to form barium carbonate and to release NOx. The latter is then reduced by the reducing
35 agents (H_2, CO and HC) present in the exhaust gas, at the precious metal component which is applied to the NOx storage catalytic converter, predominantly to form harmless nitrogen (N_2).

In the method described in laid-open specification
DE 101 13 947 A1 for regenerating a nitrogen oxide
storage catalytic converter, the regeneration of the
5   nitrogen oxide storage catalytic converter is initiated
when a predetermined threshold value for the nitrogen
oxide concentration in the exhaust gas on the output
side of the nitrogen oxide storage catalytic converter
is exceeded. In this case, the regeneration comprises a
10   first phase, in which the air/fuel mixture fed to the
internal combustion engine is comparatively greatly
enriched, and a second regeneration phase following the
first regeneration phase, in which the air/fuel mixture
fed to the internal combustion engine is comparatively
15   less enriched.

Accordingly, lowering the levels of NOx over a
prolonged period using the method described requires
alternating the operation of the internal combustion
20   engine between lean and rich conditions, but it should
be noted that the rich-burn operation which is required
for the nitrate regeneration operations diminishes the
benefit in terms of fuel consumption by the internal
combustion engine which is achieved in lean-burn
25   operation. Therefore, with a view to fuel consumption,
it is desirable for the proportion of time taken up by
lean-burn operation to be as high as possible. For this
reason, it is desirable for the regeneration duration
to be as short as possible. On the other hand, it is
30   desirable for the regeneration of the nitrogen oxide
storage catalytic converter to be as complete as
possible so that, after regeneration has taken place,
said storage catalytic converter is capable of storing
as much nitrogen oxide as possible. However, for
35   emission reasons, a breaking through of harmful
reducing agents should be avoided.

Therefore the object of the invention is to specify a

method for regenerating a nitrogen oxide storage catalytic converter as efficiently and effectively as possible.

5   This object is achieved according to the invention by a method with the features of claim 1.

In the method according to the invention, a regeneration is triggered when a triggering threshold
10 value for the nitrogen oxide concentration in the exhaust gas on the output side of the nitrogen oxide storage catalytic converter is exceeded. In this case, first of all a first regeneration mode with a constant air/fuel ratio λ_M of the air/fuel mixture burned in the
15 internal combustion engine is set. Following the first regeneration mode, according to the invention a second regeneration mode with a variable value for the air/fuel ratio λ_M is set. In the second regeneration mode, it is provided that the time rate of change
20 d λ_M/dt of the air/fuel ratio λ_M is set as a function of the mass flow of the exhaust gas flowing through the nitrogen oxide storage catalytic converter or as a function of an internal combustion engine operating variable linked with the mass flow of exhaust gas. The
25 air/fuel ratio, also referred to as the lambda value, is understood here, in the usual way, as meaning the stoichiometry ratio of the content of oxygen and the content of fuel or of reducing components in the air/fuel mixture fed to the internal combustion engine
30 or in the exhaust gas. The designation λ_M is selected below for the air/fuel ratio of the air/fuel mixture fed to the internal combustion engine. In this case, during the regeneration of the air/fuel mixture fed to the internal combustion engine, a lambda value of
35 $\lambda_M \leq 1.0$, i.e. a stoichiometric or reducing air/fuel mixture, is preferably set.

The way in which the time rate of change d λ_M/dt of the

air/fuel ratio λ_M is dependent on the mass flow of the
exhaust gas flowing through the nitrogen oxide storage
catalytic converter or on an internal combustion engine
operating variable linked with the mass flow of exhaust
5   gas is preferably selected in such a manner that the
nitrogen oxide storage catalytic converter in the
second regeneration mode is fed, given a comparatively
small mass flow of exhaust gas, with an exhaust gas
having a temporally rising content of reducing agent
10   and, given a higher mass flow of exhaust gas, with an
exhaust gas having a temporally decreasing content of
reducing agent. In addition, the dependency is
preferably selected in such a manner that, at customary
driving states of the corresponding motor vehicle, a
15   gradually rising lambda value is produced over the
course of the second regeneration phase. It is
therefore taken into account that, as the regeneration
continues, the demand for reducing agent gradually
decreases. An excess of reducing agent supplied and a
20   resultantly caused leakage of reducing agent are
therefore also avoided. Since a decreasing lambda value
is set when there is a small mass flow of exhaust gas,
the duration of time that the reducing agent spends in
the volume of the catalytic converter increases when
25   there is a small mass flow of exhaust gas, and the
reducing agent can therefore be completely converted
even at high concentration, thus avoiding leakage of
the reducing agent.

30   In a refinement of the invention, the first
regeneration mode is ended after a predeterminable
first period of time. In the first regeneration mode, a
comparatively low air/fuel ratio of approximately
$\lambda_M = 0.8$ is set. The period of time for maintaining the
35   first regeneration mode (first regeneration phase) is
also dependent on the volume of the nitrogen oxide
storage catalytic converter and is preferably selected
to be comparatively short, for example approximately

one second. The period of time and the lambda value of
the first phase of the regeneration of the nitrogen
oxide storage catalytic converter, if the latter still
has a comparatively large amount of nitrogen oxides or
5   oxygen stored in it, is preferably selected in such a
manner that a large part of the stored nitrogen oxides
or of the stored oxygen is already reduced, thus
avoiding leakage of reducing agent. The selection of
predeterminable and preferably fixedly applied values
10   for the duration and the air/fuel ratio in the first
regeneration phase takes account of the fact that,
after the lean-burn storage phase ends, a minimal
amount of nitrogen oxides is stored in the nitrogen
oxide storage catalytic converter.

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In a further refinement of the invention, the second
regeneration mode is ended after a predeterminable
second period of time. The second period of time is
preferably fixedly applied and selected in such a
20   manner that, taking the storage capacity of the
nitrogen oxide storage catalytic converter into
account, the majority of the stored nitrogen oxides is
reduced when this regeneration phase ends.

25   In a further refinement of the invention, in a third
regeneration mode, the time rate of change d λ_M/dt of
the air/fuel ratio λ_M is set as a function of the mass
flow of exhaust gas or as a function of an internal
combustion engine operating variable linked with the
30   mass flow of exhaust gas and as a function of the
measured value of a lambda probe arranged in the
exhaust pipe on the output side of the nitrogen oxide
storage catalytic converter. In this case, a lambda
probe is understood as meaning a sensor which supplies
35   a signal dependent on the lambda value of the exhaust
gas. An NOx sensor, preferably with lambda
functionality, can likewise be used. By additionally
taking into consideration the lambda value of the

exhaust gas present on the output side of the nitrogen
oxide storage catalytic converter, the regeneration
progress can be particularly reliably detected and
taken into consideration by the consequent setting of
5   the air/fuel ratio of the internal combustion engine.
An oversupplying of the nitrogen oxide storage
catalytic converter with reducing agents and an
associated leakage of reducing agent can therefore be
avoided. This is particularly important toward the end
10   of the regeneration when only small amounts of nitrogen
oxide are still stored in the nitrogen oxide storage
catalytic converter.

The third regeneration mode may be set instead of the
15   second regeneration mode, but, according to a further
refinement of the invention, the third regeneration
mode is preferably set directly after the second
regeneration mode ends.

20   In a further refinement of the invention, the setting
of the air/fuel ratio λ_M is limited to a value range
with a predeterminable lower limit value λ_{min} and a
predeterminable upper limit value λ_{max}. This measure
firstly makes it possible to avoid too sharp a drop of
25   the air/fuel ratio and therefore a leakage of reducing
agent. Secondly, it is avoided that the air/fuel ratio
rises too severely and thereby, under some
circumstances, the rich range preferred for the
regeneration is even departed from and hence
30   regeneration no longer takes place. Preferably, when
the lower limit value λ_{min} is reached, the air/fuel
ratio is kept at the lower limit value until a rise of
the air/fuel ratio is initiated again by the mass flow
of exhaust gas rising. Correspondingly, it is
35   preferably provided, when the upper limit value λ_{max} for
the air/fuel ratio is reached, to keep the latter at
this limit value until a dropping of the air/fuel ratio
is initiated again by the mass flow of exhaust gas

dropping.

In a further refinement of the invention, the triggering threshold value for triggering the regeneration of the nitrogen oxide storage catalytic converter is predetermined and/or the time rate of change $d\lambda_M/dt$ of the air/fuel ratio λ_M is set as a function of an aging factor representing the aging of the nitrogen oxide storage catalytic converter. The aging factor representing the aging is preferably derived from the current nitrogen oxide storage capacity of the nitrogen oxide storage catalytic converter and comparison with the nitrogen oxide storage capacity of the nitrogen oxide storage catalytic converter in the unaged state. The current nitrogen oxide storage capacity can be determined, for example, by measuring the leakage of nitrogen oxide during the lean storage phase and comparing it with the raw emission of nitrogen oxide from the internal combustion engine. In this case, it is advantageous to determine the storage capacity of the nitrogen oxide storage catalytic converter with predeterminable reference conditions, for example with regard to speed of rotation, load and/or exhaust gas temperature, and to compare it with a reference value, determined beforehand under the same conditions, of the unaged nitrogen oxide storage catalytic converter.

With the matching of the triggering threshold value to the aging state of the nitrogen oxide storage catalytic converter, an aging-induced dropping of the nitrogen oxide storage capacity can be reacted to. Preferably, as the nitrogen oxide storage catalytic converter increases in age, the triggering threshold value is lowered. The regeneration operations therefore take place at shorter intervals with which the lower storage capacity is taken into account. By means of the aging-dependent setting of the time rate of change $d\lambda_M/dt$ of

the air/fuel ratio λ_M in the second or in the third
regeneration phase, the aging-induced reduced amount of
stored nitrogen oxides can be reacted to and the
regeneration correspondingly adapted. Preferably, as
5 the nitrogen oxide storage catalytic converter
increases in age, a greater change of the air/fuel
ratio λ_M can be provided at a certain mass flow of
exhaust gas, so that the duration of the regeneration
is shortened.
10

The invention is explained in more detail below with
reference to drawings and associated examples. In the
drawings:

15 Fig. 1   shows a diagrammatic illustration of an
           internal combustion engine with an exhaust pipe
           in which a nitrogen oxide storage catalytic
           converter is arranged, and

20 Fig. 2   shows a diagram for clarifying a typical
           profile of the regeneration of the nitrogen
           oxide storage catalytic converter.

Fig. 1 shows, in a basic diagrammatic illustration, an
25 internal combustion engine 1 with an intake air line 2,
an exhaust pipe 3 with a nitrogen oxide storage
catalytic converter 4 arranged in it, and an electronic
engine control unit 7. The internal combustion engine 1
is designed here by way of example as a four-cylinder
30 spark-ignition engine capable of running in lean-burn
mode. In the exhaust pipe, a first exhaust gas
measuring probe 5 and a second exhaust gas measuring
probe 6 are arranged upstream and downstream of the
nitrogen oxide storage catalytic converter 4 and their
35 signal lines 8 lead to the engine control unit 7. The
engine control unit 7 is furthermore connected by a
signal line 9 to the engine 1 in order to set and
detect the operating parameters of the engine. Further

devices for controlling the operation of the engine,
such as injection valves, fuel supply, exhaust gas
recirculation, inlet air regulation and the like are
not illustrated for clarity reasons. Connections of the
5 control unit 7 to sensors for detecting further
operating variables, such as rotational speed of the
engine, current driving speed of the associated motor
vehicle, selected driving position of the transmission
and the like are not illustrated either. It goes
10 without saying, however, that the control unit 7 has
the customary possibilities for detecting and, if
appropriate, influencing the operating state of the
engine 1 and of the associated motor vehicle.
Furthermore, further exhaust gas cleaning components
15 (not illustrated here), such as, for example, a
starting catalytic converter which is preferably
arranged upstream of the nitrogen oxide storage
catalytic converter 4 and is designed as an oxidation
catalytic converter, may, of course, be present.
20

The exhaust gas measuring probes 5, 6 are preferably
designed as "lambda probes" for detecting the air/fuel
ratio of the exhaust gas, called exhaust gas lambda λ_A
below, at the corresponding point in the exhaust pipe
25 3. An embodiment of the second exhaust gas measuring
probe 6 as a combined NOx/lambda probe with which both
the nitrogen oxide content in the exhaust gas and the
air/fuel ratio thereof can be determined, is
particularly preferred. It is likewise advantageous to
30 design the second exhaust gas measuring probe as a
"binary lambda probe" with a very steep characteristic-
curve profile in a narrow range about an air/fuel ratio
of $\lambda = 1.0$. The first exhaust gas measuring probe 5 is
preferably used to regulate the air/fuel ratio λ_M of
35 the air/fuel mixture fed to the engine. It is
advantageous here to arrange the first exhaust gas
measuring probe upstream, seen in the direction of
flow, of the first exhaust gas catalytic converter

provided in the exhaust pipe 3.

Advantageous embodiments for carrying out the
regeneration of the nitrogen oxide storage catalytic
5 converter 4 are explained below, with measurement
signals of the exhaust gas measuring probes 5, 6 being
returned to. For explanation, use is made of the
diagram which is illustrated in Fig. 2 and in which a
typical profile of the air/fuel ratio λ_M is sketched.
10 The corresponding values can be supplied by the lambda
probe 5 as measured values.

Starting from a lean storage phase 10, a switch is made
into the regeneration mode which comprises three
15 consecutive regeneration phases 11, 12, 13 in which
three different regeneration modes are set. When the
third regeneration phase 13 ends, a switch is made back
again into a further lean storage phase 14.

20 The regeneration of the nitrogen oxide storage
catalytic converter 4 is preferably triggered by the
engine control unit 7 when a threshold value for the
nitrogen oxide concentration detected on the output
side of the nitrogen oxide storage catalytic converter
25 by the exhaust gas measuring probe 6 is reached. The
nitrogen oxide concentration can also be evaluated with
the current mass flow of exhaust gas $m_{Exhaust\ gas}$, so that
the mass flow of nitrogen oxide on the output side of
the nitrogen oxide storage catalytic converter 4 is
30 obtained, and, when a corresponding threshold value for
the mass flow of nitrogen oxide is reached, the
regeneration is triggered. It is likewise advantageous
to integrate the mass flow of nitrogen oxide during the
lean storage phase 10, as a result of which an integral
35 value for the leakage of nitrogen oxide during the lean
storage phase is obtained. In this case, the
regeneration is triggered when a threshold value for
the integral leakage of nitrogen oxide is reached. A

typical profile of the regeneration is explained below.

After the regeneration has been triggered, for a first
regeneration phase 11 first of all a first regeneration
5   mode with a comparatively rich air/fuel ratio of
approximately $\lambda_M = 0.8$ is preferably set suddenly and
is maintained for a predeterminable first period of
time. This first period of time is preferably
programmed into the engine control unit 7 and is
10 approximately one second. However, it can also be
provided to adapt the first period of time adaptively
to the storage capacity or to the aging of the nitrogen
oxide storage catalytic converter 4 and, if
appropriate, to change, preferably to shorten it. This
15 is discussed in more detail further below.

After the first period of time for the first
regeneration phase 11 has elapsed, the second
regeneration phase 12 is transferred to and, in a
20 second regeneration mode, the air/fuel ratio λ_M is
changed as a function of the mass flow of exhaust gas
$m_{Exhaust\ gas}$. For this, it is provided to set the time rate
of change $d\lambda_M/dt$ of the air/fuel ratio λ_M as a function
of the mass flow $m_{Exhaust\ gas}$ of the exhaust gas flowing
25 through the nitrogen oxide storage catalytic converter
4. However, instead of the mass flow of exhaust gas
$m_{Exhaust\ gas}$, use may also be made of an internal
combustion engine operating variable linked with the
mass flow of exhaust gas $m_{Exhaust\ gas}$, such as, for
30 example, the rotational speed of the engine and/or the
engine load. The time rate of change $d\lambda_M/dt$ of the
air/fuel ratio λ_M is preferably set as a function of
the mass flow of exhaust gas $m_{Exhaust\ gas}$ in accordance
with a characteristic diagram stored in the engine
35 control unit 7. However, a functional dependency stored
in the engine control unit 7 may also be used for
setting the time rate of change $d\lambda_M/dt$ of the air/fuel
ratio λ_M. For example, a linear dependency is

illustrated in diagram form in Fig. 3.

The continuing sequence of the regeneration of the
nitrogen oxide storage catalytic converter 4 is
5   explained below with reference to Figs 1 to 3. The
dependence of the time rate of change d λ_M/dt on the
air/fuel ratio λ_M with d λ_M/dt = f($m_{Exhaust\ gas}$) is
described here. It goes without saying that a
functional dependency for the change d λ_M/dt of the
10 air/fuel ratio λ_M on the mass flow of exhaust gas $m_{Exhaust\ gas}$ different from the linear dependency illustrated in
the diagram of Fig. 3 may also be provided. For
example, a stepped dependency is also advantageous.
This can be stored in the engine control unit 7 in the
15 form of a table of values or in the form of a
characteristic diagram. In each case, a dependency
d λ_M/dt = f($m_{Exhaust\ gas}$) is provided with which, under
customary engine operating states, a gradual rise of
the air/fuel ratio λ_M is produced.
20

According to the dependency illustrated in Fig. 3, a
value range exists for the mass flow of exhaust gas
$m_{Exhaust\ gas}$ to which negative values for the change
d λ_M/dt of the air/fuel ratio are assigned and
25 therefore in which a dropping of the air/fuel ratio λ_M
is set. Similarly, there is a value range for the mass
flow of exhaust gas $m_{Exhaust\ gas}$ to which positive values
for d λ_M/dt are assigned and therefore in which a
rising of the air/fuel ratio λ_M is set. According to
30 the example of the air/fuel ratio profile illustrated
in Fig. 2, in the time sections 15, 17, 19 there is a
mass flow of exhaust gas $m_{Exhaust\ gas}$ in which the air/fuel
ratio λ_M rises in accordance with the dependency
illustrated in Fig. 3. By contrast, in the time section
35 18 there is a mass flow of exhaust gas $m_{Exhaust\ gas}$ in
which the air/fuel ratio λ_M drops in accordance with
the dependency illustrated in Fig. 3. Correspondingly,
in the time section 16 there is a mass flow of exhaust

gas $m_{Exhaust\ gas}$ in which a constant air/fuel ratio λ_M is set in accordance with the dependency illustrated in Fig. 3. Preferably, however, a rising or a dropping of the air/fuel ratio λ_M is set only if a predeterminable upper limit value λ_{max} of, for example, $\lambda_{max} = 0.95$ or a lower limit value λ_{min} of, for example, $\lambda_{min} = 0.8$ for the air/fuel ratio λ_M is not reached.

The corresponding procedure is clarified in the sequence diagram illustrated in Fig. 4. Accordingly, after entering the second regeneration phase 12, it is asked in the interrogation block 22 whether the air/fuel ratio λ_M is greater than a predeterminable lower limit value λ_{min}. If this is not the case, then a constant air/fuel ratio λ_M is set by the function block 23. If the air/fuel ratio λ_M is greater than a predeterminable lower limit value λ_{min}, then the interrogation block 24 is continued to and it is asked whether the air/fuel ratio λ_M is lower than a predeterminable upper limit value λ_{max}. If this is not the case, then a constant air/fuel ratio λ_M is set by the function block 23, otherwise, with the function block 25, a change $d\lambda_M/dt$ of the air/fuel ratio is undertaken in accordance with a preprogrammed, functional dependence $d\lambda_M/dt = f(m_{Exhaust\ gas})$ on the mass flow of exhaust gas $m_{Exhaust\ gas}$, for example in accordance with the dependency illustrated in the diagram of Fig. 3.

The second regeneration phase 12 is preferably ended after a second period of time programmed into the engine control unit and the continuous running through the sequence diagram according to Fig. 4 is terminated. However, it may also be provided to match the second period of time adaptively to the storage capacity or to the aging of the nitrogen oxide storage catalytic converter and, if appropriate, to change, preferably to shorten it.

After the second period of time for the second
regeneration phase 12 expires, the third regeneration
phase 13 is transferred to. In the latter, in a third
5 regeneration mode for setting the air/fuel ratio λ_M, in
addition to the mass flow of exhaust gas $m_{Exhaust\ gas}$ the
air/fuel ratio λ_A of the exhaust gas detected on the
output side of the nitrogen oxide storage catalytic
converter 4 or the output signal, which is related
10 thereto, of the second exhaust gas measuring probe 6 is
taken into consideration. For this purpose, it can be
provided to derive from the detected air/fuel ratio λ_A
a first correction factor k_1 which, for example, is
proportional thereto and with which the value
15 determined as described above for the change d λ_M/dt of
the air/fuel ratio λ_M is multiplied as a function of
the dependency d $\lambda_M/dt = f(m_{Exhaust\ gas})$. In the case of a
first correction factor k_1 which is proportional to the
air/fuel ratio λ_A, it is advantageous to link the
20 proportionality with the value of the air/fuel ratio λ_A
at the beginning of the third regeneration phase 13, as
a result of which the progress of the regeneration can
be evaluated. The method sequence in the third
regeneration phase 13 therefore corresponds to the
25 sequence diagram, illustrated in Fig. 4, for the second
regeneration phase 12, with, in contrast to the method
sequence of the second regeneration phase 12, in
function block 25 the correspondingly changed entry
d $\lambda_M/dt = k_1*f(m_{Exhaust\ gas})$ now having to be taken into
30 consideration.

Since, as the regeneration progresses further, the
air/fuel ratio λ_A of the exhaust gas approaches the set
air/fuel ratio λ_M from above, in accordance with the
35 regeneration section, which is provided with the
reference number 20 in Fig. 2, the air/fuel ratio λ_M is
further "raised". If the upper limit value λ_{max} is
reached, then the air/fuel ratio λ_M remains at this

upper limit value unless a dropping of the air/fuel
ratio λ_M is caused by a very severe dropping of the
mass flow of exhaust gas. This retention of the
air/fuel ratio λ_M corresponds to the regeneration
section provided with the reference number 21 in
Fig. 2.

The regeneration is ended and a transfer is made to an
engine operation with a lean or stoichiometric air/fuel
ratio λ_M if the second exhaust gas measuring probe 6 on
the output side of the nitrogen oxide storage catalytic
converter 4 drops below a predeterminable lower
threshold value for the air/fuel ratio λ_A of the
exhaust gas of, for example, $\lambda_A = 0.98$, which would
correspond to a breakthrough of reducing agent. In
particular in the case of a second exhaust gas
measuring probe 6 designed as a "binary probe", it is
advantageous, on account of the steep characteristic
curve profile around $\lambda = 1.0$, to end the regeneration
if the measurement signal of this probe exceeds a
predeterminable upper limit value. It is assumed here
that the measurement signal of the second exhaust gas
measuring probe 6, which is designed as a binary probe,
behaves in an opposed manner to the value of the
air/fuel ratio λ_A. The ending of the regeneration may,
however, also take place on the basis of a computer
model stored in the engine control unit 7. In this
case, the regeneration is ended if the amount of
reducing agent entered overall into the nitrogen oxide
storage catalytic converter exceeds the amount of
reducing agent necessary for reducing the amount of
nitrogen oxide stored at the beginning of the
regeneration. It is particularly advantageous to end
the regeneration if one of the two mentioned criteria
occurs. In this connection, it is advantageous to
correct or to adapt the stored computer model for the
balancing of the reducing agent with the aid of the
measured value supplied by the exhaust gas measuring

probe 6 with the effect of obtaining the best possible
correspondence.

5 The explained procedure according to the invention for
regenerating a nitrogen oxide storage catalytic
converter 4 can be advantageously matched to an aging,
which increases over the course of time, of the
nitrogen oxide storage catalytic converter 4. Such
aging may occur, for example, because of sulfuric
10 poisoning, which increases over the course of time, due
to the sulfur present in the fuel. In said poisoning,
sulfur is embedded in the form of sulfates in the
nitrogen oxide storage catalytic converter 4, which
reduces its storage capacity for nitrogen oxides.
15 However, an aging with a corresponding decrease in the
nitrogen oxide storage capacity can also be caused by
thermal overloading.

In order to detect and to evaluate the state of aging
20 of the nitrogen oxide storage catalytic converter 4, it
is therefore provided to determine its nitrogen oxide
storage capacity continuously or from time to time. For
this purpose, during the lean storage phase, the
leakage of nitrogen oxide emerging from the nitrogen
25 oxide storage catalytic converter 4 is determined, for
example, by means of the exhaust gas measuring probe 6
and is compared with the entry of nitrogen oxide. The
latter can be provided on the basis of a nitrogen oxide
emission characteristic diagram of the engine 1 that
30 has been placed in the engine control unit 7. According
to the invention, it is provided to form an aging
factor from the decrease, which is established in
comparison to the state when new, of the nitrogen oxide
storage capacity of the nitrogen oxide storage
35 catalytic converter 4 and to use this aging factor to
match the regeneration or the alternating operation of
the engine 1 under lean-burn and rich-burn conditions
to the aging state of the nitrogen oxide storage

catalytic converter 4.

For this purpose, it is advantageous to reduce the threshold value, which is decisive for the triggering

5 of the regeneration, for the nitrogen oxide concentration detected on the output side of the nitrogen oxide storage catalytic converter 4 or the threshold value for the integral leakage of nitrogen oxide in the lean storage phase, as a function of the

10 aging factor. This can take place proportionally, in the simplest case, in accordance with a predetermined, suitable, functional dependence. Furthermore, it is advantageous to adapt the first period of time for the first regeneration phase 11 and/or the second period of

15 time for the second regeneration phase 12 as a function of the aging factor. This can likewise take place in accordance with a predetermined, suitable, functional dependency. In the simplest case, the first and/or the second period of time are shortened proportionally to

20 the aging factor.

According to the invention, it is furthermore provided to set the functional dependency $d\,\lambda_M/dt = f(m_{Exhaust\ gas})$ of the time rate of change $d\,\lambda_M/dt$ of the air/fuel

25 ratio λ_M in the second regeneration phase 12 and/or the functional dependency $d\,\lambda_M/dt = k_1*f(m_{Exhaust\ gas})$ in the third regeneration phase 13 as a function of the aging factor. For this purpose, it is advantageous, when carrying out the method for the second regeneration

30 phase 12, which corresponds to the sequence diagram illustrated in Fig. 4, now to take the changed entry $d\,\lambda_M/dt = k_2*f(m_{Exhaust\ gas})$ into consideration in the function block 25, with the second correction factor k_2 corresponding to the aging factor of the nitrogen oxide

35 storage catalytic converter 4 or being derived therefrom. Similarly, when analogously carrying out the method of the third regeneration phase 13, according to the sequence diagram illustrated in Fig. 4, the changed

entry d $\lambda_M/dt = k_1*k_2*f(m_{Exhaust\ gas})$ is now taken into consideration in the function block 25.

Values for the aging factor or the second correction factor k_2 can be determined by preliminary tests with storage catalytic converters aged to differing extents and can be deposited in the engine control unit 7.